ABSTRACT

The present work is focused on the Graphene-based nanofluids with high thermal conductivity which helps to improve the performance and enhance heat transfer. The thermal systems emphasis on the fluid coolant selection and statistical model. Graphene is a super-material, lighter than air, high thermal conductivity, and chemical stability. The purpose of the research is to work up with Graphene-based Nanofluids i.e., Graphene (G) and Graphene oxide (GO). Nanoparticles are dispersed in a base fluid with a 60:40 ratio Water & Ethylene Glycol and at different volume concentrations ranging from 0.01%–0.09%. Radiator model is designed in modelling software and louvered strip is inserted. The simulation (Finite Element Analysis) is performed to evaluate variation in temperature drop, enthalpy, entropy, heat transfer coefficient and total heat transfer rate of the considered nanofluids, results were compared by with and without louvered strip in the radiator for the temperature absorption. 58–60% enhancement of enthalpy observed when Graphene and Graphene oxide nanofluid was utilized. 1.8% enhancement of entropy is observed in 0.09% volume concentration of the Graphene and Graphene oxide nanofluid when louvered strips are inserted in the radiator tube at a flow rate of 3 LPM. With louvered strip inserted in the radiator, heat transfer coefficient enhanced by 236% for Graphene and 320% enhancement is identified for Graphene oxide nanofluid when compared to without louvered strip insert. The results stated that high performance is observed with the utilization of louvered strip in the radiator tube.

INTRODUCTION

The Heat exchangers are the set of things working together as parts of a mechanism used to transfer heat from two or more fluids. One such kind of a heat exchanger is a radiator which can transfer the sensible heat termed as thermal energy to cool or heat from one medium to other [1–3]. To improve the performance of the engine, it is very much essential to deploy an efficient cooling system [4]. Cooling systems are designed with an expanded ability to throw away a considerable quantity of waste heat, thereby improving engine efficiency [5]. Conventional cooling approach made use of fins in radiators to increase the cooling capacity. Irrespective of the improved cooling capacity, the fundamental approach of using fins has become extinct due to an increase in the size of the radiator. The radiator is an essential element in any engine system as it is the fundamental component of the cooling system [1, 6]. The efficiency of an automobile engine is measured on high fuel economy, low emissions along with the performance of the engine [7]. The heat transfer fluid could not meet the design criteria to increase the thermal efficiency of the heat exchanger. Hence, there is huge scope and opportunity for new heat transfer fluids which can help to improve heat transfer rate [8]. Nanofluids act as an efficient coolant, when nanoparticles are mixed with base fluids such as ethylene glycol to improve the capacity of heat transfer in the radiator by an approximate value between 15–40% [9].

The purpose of the research is to work up with Graphene based Nanofluids i.e., Graphene (G) and Graphene Oxide (GO). Radiator model is designed in modelling software (CREO) and louvered strip is inserted. The simulation (Finite Element Analysis) is carried out using Ansys Workbench tool to estimate the variation in temperature drop, enthalpy, entropy, heat transfer coefficient and the heat transfer rate of the considered nanofluids, the results were compared with and without louvered strip in the radiator for the temperature absorption. The objective of the research is to design the radiator in a modeling software and perform finite element analysis and evaluate the performance of heat transfer of a Radiator with and without Louvered Strip by using Graphene-based Nanofluids and to present the difference in radiator performance with the insertion of louvered strip. This insertion of a louvered strip in radiator tube is a new design and has never been used before.

THEORY

Generally, water, ethylene glycol (antifreeze), oil is used as traditional fluids [10, 11]. In the past decade's number of researchers have carried various investigations to increase the thermal properties of the conventional fluids [12, 13]. Colloidal dispersions of various nanoparticles with the conventional base fluid result in the formation of Nanofluids [14–16]. Heris, Shokrgozar [17] identified that the nanometer size particles, when dissolved in any traditional conventional fluids, will increase the heat transfer. Different works of literature pronounced that the thermal execution of various heat systems can be improvised by adopting various Nano-fluids with nanoparticles like Al₂O₃, CuO, and Graphene as an active working fluid [18–21]. Graphene, as a Nano-fluid, is used intensively as a cooling element [22]. Graphene nanofluids have gained massive attention because of its high thermal conductivity value than carbon nanotubes, oxide ceramics (Al₂O₃, CuO, SiO₂, TiO₂ etc.) in thermal applications such as in photovoltaic system and heat transfer applications [16, 23, 24]. Graphene has a hexagonal structure which is like a honeycomb with largely dense carbon atoms [25]. The research papers which are published in various journals by Scopus is retrieved by keyword Graphene nanofluids from 2010–2020 is listed in the below graph of Figure 1.

This pattern is identical to the structure of various nanostructured materials, such as fullerene and carbon nanotubes [26]. Thermal conductivity of Graphene Nanoparticles is approximately 4000 to 5000 w/m-k, this can be synthesized by various techniques. Graphene formed by graphite, and it is also synthesized using epitaxial and CVD growth methods [27]. Graphene has high surface area of 2630 sq.mt/gm [28] and high electrical conductivity 13x times better than copper [29] and acts as a best heat conductor than Diamond [30].

THERMOPHYSICAL PROPERTIES OF THE NANOFLUIDS

The nanofluid thermophysical properties comprises of different volume concentration, density, viscosity, and thermal conductivity. The Thermophysical properties show the key finding that the nanofluid is efficient and enables the researcher to find better measurement to compare the nanofluids to conventional fluids.

The Volume Concentration of The Fluid

In the current study, nanofluid preparation is based on two-step technique. Nanoparticles were weighed based on the volume concentration by using weighing balance machine. Based on the volume concentration of fluid, the quantity of nanoparticles is dispersed in the base fluid. Following equation helps in finding required quantity of the nanoparticles [31].

$$\phi = \left( \frac{\frac{w}{\rho_p}}{\frac{w}{\rho_p} + \frac{w_{nf}}{\rho_{nf}}} \right) \times 100$$ (1)
was considered as active fluid for pulsating heat pipes. GO was mixed with base fluid, water (0.25, 0.5, 1, and 1.5 g/lit). Results indicated that addition of GO improved base fluid thermal conductivity. The thermal resistance of pulsating heat pipe was reduced up to 42% [41]. The max. enhancement of thermal conductivity at max. relative concentration is obtained at value of 0.02 vol% reduced Graphene Oxide (rGO) with 1 vol% SDBS surfactant (sodium dodecylbenzene sulfonate). The rGO exhibited optimum stability and thermal conductivity, whereas viscosity value is reduced when equated to 0.02 and 0.05 vol% rGO without using any surfactants. While using 1 vol% of SDS (Sodium dodecyl sulfate) surfactant, the value of zeta potential increased 30.7 mV to 52.2 mV . Enhancement from 2.6% to 3.9% is exhibited for thermal conductivity, reduction in viscosity progressed from 8.8% to 12.2% [42]. The Graphene Oxide (GO) and Graphene Nano Ribbons (GNR) nano-fluids were obtained by using pure water as base fluid. Enhancement of Heat transfer is calculated by using experimental data of pure water and nanofluids heat transfer coefficients (U). 5.41% and 26.08% are the mean enhancement values (U) obtained at 0.01% and 0.02% vol. concentrations of GO/water nano-fluid at all temperature. GNR and water nano-fluids obtained 15.62% and 20.64% enhancement values for 0.01% and 0.02% vol. concentrations respectively [43]. The studied results of Hamze, Berrada [44] stated that the concentration of FLG (Few layer Graphene) nanosheets varies between 0.05 and 0.5% in mass. Figure 8 shows that nanofluids thermal conductivity increased with FLG content. FLG concentration of 0.05, 0.10, 0.25, and 0.50 wt.%, thermal conductivity of nanofluid increases by 4.2, 5.5, 12.2, and 23.9%, respectively, as compared to the corresponding base fluid.

Density and Specific Heat of The Fluid
Nanofluids density (Eq.2) is measured based on the following equations. The values of density and specific heat of the nanoparticles are considered from vendor. The parameter of concentration of nanofluid is considered the effective density [10]

$$\rho_{nf} = \phi \rho_s + (1 - \phi) \rho_f$$  \hspace{1cm} (2)

The specific heat of the nanofluid is measured using below (Eq.3). It’s a purpose of concentration and base fluid specific heat [32].

$$C_p_{nf} = \frac{\phi (\rho C_p) + (1 - \phi) (\rho C_p)_f}{\rho_{nf}}$$ \hspace{1cm} (3)

Thermal Conductivity
Thermal conductivity has an important role in heat transfer applications [33]. Many researchers focused to improve the thermal conductivity of the fluid in experimentally, numerically also by many case studies. Maxwell [34] equation is utilized by many researchers to find the thermal conductivity with different volume ratio and some of the thermal conductivity formulas are mentioned in the following Table 1.

Thermal conductivity value increased by 27% for 0.2% volume concentration of Graphene nanofluids. A linear rise in electrical conductivity was observed with increase in particle volume concentration [39]. It showed a peak value of 56.45% and 41.47% thermal conductivity enhancement in efficiency at 40°C and 50°C [40]. GO nano-fluid was considered as active fluid for pulsating heat pipes. GO was mixed with base fluid, water (0.25, 0.5, 1, and 1.5 g/lit). Results indicated that addition of GO improved base fluid thermal conductivity. The thermal resistance of pulsating heat pipe was reduced up to 42% [41]. The max. enhancement of thermal conductivity at max. relative concentration is obtained at value of 0.02 vol% reduced Graphene Oxide (rGO) with 1 vol% SDBS surfactant (sodium dodecylbenzene sulfonate). The rGO exhibited optimum stability and thermal conductivity, whereas viscosity value is reduced when equated to 0.02 and 0.05 vol% rGO without using any surfactants. While using 1 vol% of SDS (Sodium dodecyl sulfate) surfactant, the value of zeta potential increased 30.7 mV to 52.2 mV . Enhancement from 2.6% to 3.9% is exhibited for thermal conductivity, reduction in viscosity progressed from 8.8% to 12.2% [42]. The Graphene Oxide (GO) and Graphene Nano Ribbons (GNR) nano-fluids were obtained by using pure water as base fluid. Enhancement of Heat transfer is calculated by using experimental data of pure water and nanofluids heat transfer coefficients (U). 5.41% and 26.08% are the mean enhancement values (U) obtained at 0.01% and 0.02% vol. concentrations of GO/water nano-fluid at all temperature. GNR and water nano-fluids obtained 15.62% and 20.64% enhancement values for 0.01% and 0.02% vol. concentrations respectively [43]. The studied results of Hamze, Berrada [44] stated that the concentration of FLG (Few layer Graphene) nanosheets varies between 0.05 and 0.5% in mass. Figure 8 shows that nanofluids thermal conductivity increased with FLG content. FLG concentration of 0.05, 0.10, 0.25, and 0.50 wt.%, thermal conductivity of nanofluid increases by 4.2, 5.5, 12.2, and 23.9%, respectively, as compared to the corresponding base fluid.
of 0.001–0.01% [49]. The viscosity of functionalized graphene (f-HEG) was studied by [50]. f-HEG along with Ethylene Glycol & water 70/30 ratio combined at 0.041 – 0.395% concentration was recorded with 100 % increment as compared with non-Newtonian behavior base fluid. Graphene Oxide – Ethylene Glycol nanofluid obtained maximum viscosity value of 81.29 cP (pascal-second) at temperature value 20 °C, GO nanosheets mass concentration 0.005, at shear rate of 25 s −1. Nanofluids viscosity diminished non-linearly for an increasing shear rate, displaying solid “shear-diminishing” conduct at lower shear rates. Nanofluids viscosity diminished fundamentally when temperature value increases, Viscosity enhances when mass concentration increases [51]. 13.4%, 14.4% and 15.8% are the maximum viscosity values at 25°C, 50°C and 70°C correspondingly. After 4 days testing, Viscosity of nanofluid recorded less values as compared with base fluid [42].

### Heat Transfer Characteristics

Thermal conductivity of the material or fluid is high, the value of heat transfer coefficient similarly increases along fluids when using Triton X-100 as a surfactant. The thermal conductivity enhancements are 1.3, 3.0, 9.9, and 18.3% for P-123, Pluronic. Finally, using Gum Arabic, thermal conductivity values increased by 2.1%, 4.0%, 10.5%, and 21.5%.

### Viscosity

Einstein [45] proposed the viscosity model in 1881, (Eq.10). Using the flow around one particle, the viscosity of dilute suspension of small particles are calculated [46]. Volume concentration can also be applied to use the Einstein viscosity model. Later, many researchers have improved the viscosity model to find the nature of the viscosity based on its shape and size, most of research studies are focused on finding nanofluids and hybrid nanofluids thermal conductivity as well as viscosity. The viscosity of a fluid is the measure of its resistance to gradual deformation by shear stress or tensile stress. A few viscosity models are given in below Table 2.

The viscosity values observed the increment for Graphene & DW nanofluid with higher value (>1.2 times at 15μm compared with 5μm size) at a volume concentration of 0.001–0.01% [49]. The viscosity of functionalized graphene (f-HEG) was studied by [50]. f-HEG along with Ethylene Glycol & water 70/30 ratio combined at 0.041 – 0.395% concentration was recorded with 100 % increment as compared with non-Newtonian behavior base fluid. Graphene Oxide – Ethylene Glycol nanofluid obtained maximum viscosity value of 81.29 cP (pascal-second) at temperature value 20 °C, GO nanosheets mass concentration 0.005, at shear rate of 25 s −1. Nanofluids viscosity diminished non-linearly for an increasing shear rate, displaying solid “shear-diminishing” conduct at lower shear rates. Nanofluids viscosity diminished fundamentally when temperature value increases, Viscosity enhances when mass concentration increases [51]. 13.4%, 14.4% and 15.8% are the maximum viscosity values at 25°C, 50°C and 70°C correspondingly. After 4 days testing, Viscosity of nanofluid recorded less values as compared with base fluid [42].

### Heat Transfer Characteristics

Thermal conductivity of the material or fluid is high, the value of heat transfer coefficient similarly increases along

#### Table 1. Thermal conductivity equations given by different authors

<table>
<thead>
<tr>
<th>Author</th>
<th>Formula</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxwell [34]</td>
<td>[ k_{\text{eff}} = \frac{k_{\text{p}} + 2k_{\text{f}} + 2(k_{\text{p}} - k_{\text{f}})\phi}{k_{\text{p}} + 2k_{\text{f}} - (k_{\text{p}} - k_{\text{f}})\phi} ]</td>
<td>(4)</td>
</tr>
<tr>
<td>Hamilton and Crosser [35]</td>
<td>[ k_{\text{eff}} = \frac{k_{\text{p}} + (n-1)k_{\text{f}} - (n-1)(k_{\text{p}} - k_{\text{f}})\phi}{k_{\text{p}} + (n-1)k_{\text{f}} + (k_{\text{p}} - k_{\text{f}})\phi} ]</td>
<td>(5)</td>
</tr>
<tr>
<td>Charunyakorn, Sengupta [36]</td>
<td>[ \psi = \frac{(6V_p)^{2/3} \pi}{A_p} ]</td>
<td>(6)</td>
</tr>
<tr>
<td>Xue [37]</td>
<td>[ k_{\text{eff}} = \frac{k_{\text{p}} + 2k_{\text{f}} - 2\phi(k_{\text{p}} - k_{\text{f}})}{k_{\text{p}} + 2k_{\text{f}} + \phi(k_{\text{p}} - k_{\text{f}})} (1 + b\phi\beta_{\text{p}}) ]</td>
<td>(7)</td>
</tr>
<tr>
<td>Yu and Choi [38]</td>
<td>[ K_{\text{c,j}} = \frac{a b c}{(a+t)(b+t)(c+t)} ]</td>
<td>(8)</td>
</tr>
</tbody>
</table>

Where, \( n = \frac{3}{\psi} \)
Table 2. Viscosity equations given by different authors.

<table>
<thead>
<tr>
<th>Author</th>
<th>Formula for viscosity</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wang, Xu [47]</td>
<td>$\mu_{eff} = 1 + 7.3\phi + 123\phi^2$</td>
<td>(9)</td>
</tr>
<tr>
<td>Einstein [45]</td>
<td>$\mu_{eff} = \mu(1 + 2.5\phi)$</td>
<td>(10)</td>
</tr>
<tr>
<td>Sreedhar, Rao [48]</td>
<td>$\mu_{eff} = \frac{c_f(b)\mu b}{k_{b(f)}}$</td>
<td>(11)</td>
</tr>
</tbody>
</table>

Here $u$ and $v$ are the $x$ and $y$ velocity components respectively, $\tau_{xy}$ is shear stress & $\rho$ is the density of non-Newtonian fluid.

v) k-epsilon model

\[
\frac{\partial (\rho k)}{\partial t} + \frac{\partial (\rho \varepsilon)}{\partial x_i} = \frac{\partial}{\partial x_j} \left( \mu + \frac{\mu_t}{\sigma_k} \frac{\partial k}{\partial x_j} \right) + P_e + P_s - \sigma \varepsilon - Y_{\kappa} + S_k
\]  

For dissipation $\varepsilon$

\[
\frac{\partial (\rho \varepsilon)}{\partial t} + \frac{\partial (\rho \varepsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j} \left( \mu_t + \frac{\mu_t}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial x_j} \right) + C_{\mu} \frac{\varepsilon}{k} (P_e + C_{\mu} P_s) - C_{\omega} \rho \varepsilon^2 + S_\varepsilon
\]  

Boundary Conditions

The Radiator model is developed in CREO, a 3D modeling software by using various tools like Sketch, extrude, draft and assembly. Dimensions of the Radiator & Louvered strip [57] are presented in the Table 3. Once the radiator design is completed as shown in Figure 2 (a), the louvered strip is inserted into the radiator as shown in below Figure 2(b).

The main boundary conditions of the simulations applied for the radiator are below:

- Input flow rate = 3,4,5,6 and 7 LPM
- Maximum Inlet temperature = 353K
- Volume concentrations of nanofluids = 0.01, 0.03, 0.05 and 0.09%

The radiator will be undergone with finite element analysis (FEA) with hexagonal fine meshing as shown in Figure 3 (a) & (b) and it is solving the turbulence of k-epsilon model. The results show that it obtained 380253 nodes and 298520 elements without louvered strip and 462015 nodes and 331523 elements are obtained with the louvered strip. The elemental and orthogonal quality of the mesh along with skewness is detailed in Table 4, Mesh sensitivity is presented in Table 5.

<table>
<thead>
<tr>
<th>Table 3. Details of the radiator dimensions &amp; louvered strip</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Louvered strip details</strong></td>
</tr>
<tr>
<td>Angle of the strip = 30°</td>
</tr>
<tr>
<td>Thickness = 1mm</td>
</tr>
<tr>
<td>Length = 10mm</td>
</tr>
<tr>
<td>Pitch = 30mm</td>
</tr>
<tr>
<td>Number of Tubes = 31</td>
</tr>
</tbody>
</table>
Using the k–ε turbulence model with improved wall treatment, a steady-state simulation was performed. Recent studies revealed that the k–ε turbulence model has yielded positive results in terms of measurement. This method was allowed to run 500 iterations and converged to converge $10^{-5}$. The plot of residuals with a number of iterations is shown in Figure 4.

The thermophysical properties are calculated for the Graphene and Graphene Oxide nanofluids with the base fluid as Water: Ethylene glycol (60:40). The volume concentration is 0.01, 0.03, 0.05 and 0.09. The density, specific heat, thermal conductivity, and viscosity were calculated based on equations (2),(3),(4) and (11). The pressure drops, temperature drop, enthalpy, entropy, heat transfer coefficients etc., are estimated by using CFD. In the following images, the maximum value is indicated by red and minimum value is indicated by blue colour. From the Temperature distribution of radiator image, with and without louvered strip of Figure 5 and 6 explains that, the fluid temperature about 353K will be applied into the radiator at the inlet and pass through the tubes, with given forced convection the temperature reduction will take place. At the outlet point of the radiator it is observed that temperature gradually decreases from inlet to the outlet.

**RESULTS AND DISCUSSIONS**

For the original radiator and louvered strip inserted radiator, the pressure drop is very huge due to inserted strips. In the original model, the fluid is passed through the radiator tubes without any disturbance, but then with an obstacle there creates the turbulence which caused drop in pressure, velocity, temperature.

There is 80–86% (50kpa to 74kpa) drop observed in louvered strip radiator compared with the original radiator.
(10 kPa to 10.6 kPa), which seems that pressure is reduced in working fluid. This result is observed for both fluids. The author Karthik, Kumaresan [58] by changing of louvered strip angle from 26˚C to 30˚C, then pressure drop is 42.3%. The pitch is maintained 0.8 mm with same angles, it is noticed that 90.1% pressure drop is enhanced when the water is utilized.

where M refers to modified radiator model with insert in the tube. In Figure 7, G (0.01) is Graphene nano particles at 0.01 % concentration and G (0.01) M is the concentration of the Graphene with louvered strip inserted in the radiator tube, similarly GO indicates Graphene Oxide at their respective concentrations with and without louvered strip inserted. Thermal conductivity plays a prominent role in heat transfer. The fluid which has high thermal conductivity will be having high heat transfer rate. Water with ethylene glycol has a high transfer rate so this fluid is mostly used in the radiators. But, to achieve a high heat transfer coefficient value, thermal conductivity of the fluid needs to be increased. In this research, the Graphene nanoparticles are added at various concentrations to the base fluid for obtaining high thermal conductivity. 23–31% of pressure drop is identified when the combination of water with ethylene glycol (60:40) used and when compared with water. i.e., 4.4 to
6.2°C drop was observed in water whereas for the water + ethylene glycol 6.4 to 8.2°C drop is observed.

When the Graphene based nanofluid is used in this radiator, the temperature drop is very huge. It was observed that 34 to 45% (11 to 14°C) of the temperature drop when Graphene and Graphene oxide nanofluid is used with different concentration and mass flow rate. The highest temperature drop is observed at 3LPM because the mass flow rate is inversely proportional to temperature. 0.2 to 1°C variation is observed in between Graphene with different volume concentration along with different mass flow rate and similarly for the Graphene oxide. In between Graphene and Graphene oxide, the temperature drop is 0.5 to 2% is varied based on the different flow rate.

The louvered strip is inserted in the radiator and simulated to identify the temperature drop. 4.5 to 8.3°C variation is observed in between the Graphene with different volume concentration along with different mass flow rate and similarly for the Graphene oxide. In between Graphene and Graphene oxide, the temperature drop is 1 to 4% is varied based on the different flow rate. When compared to with and without louvered strip radiator, it was found that 27 to 42 % improvement in temperature drop for louvered strip radiator.

Temperature is directly proportional to enthalpy and entropy. Temperature of fluid depends on the engine condition, here about 353k temperature of fluid is entered into the radiator, different fluids are investigated to identify the maximum temperature drop. From the Figure 8, the results...
stated that the temperature drop is high for the less mass flow rate similarly, enthalpy is also high at a low mass flow rate.

Enthalpy is a thermodynamic property of a system. The sum of the internal energy added to the product of the pressure and volume of the system. It shows non-mechanical work and also capacity to release heat. As obtained below from Figure 9, 14.5 – 15.5% improvement of enthalpy for the water+ ethylene glycol is obtained compared with only water. 58–60% enhancement of enthalpy observed when Graphene and Graphene oxide nanofluid was utilized. Nanofluid thermophysical properties have improved the enthalpy. Less than 0.1% improvement is observed in-between Graphene and Graphene oxide with different mass flow rate along with volume concentration of the nanofluid for the original radiator. With louvered strip inserted radiator, the enthalpy improvement of Graphene is observed at 1.5% and Graphene oxide nanofluid achieved 2.5% increment of enthalpy.

Entropy is directly proportional to temperature and enthalpy. The results from Figure 10, indicate that when the mass flow rate increases, the entropy is slightly decreased. 8.5 to 13.2% entropy increased when the water with ethylene glycol is used as a fluid used in radiator. The entropy is increased to 19% when the Graphene and Graphene oxide nanofluid is utilized. Internally utilization of different volume concentration of the nanofluid, it was stated that 0.6% enhancement for the Graphene nanofluid and 1.3% enhancement for the Graphene oxide nanofluid. It seems that Graphene oxide plays a major role to achieve high entropy. 1.8% enhancement of entropy is observed in 0.09 volume concentration of the nanofluid at 3LPM when strips are inserted in the radiator i.e., high entropy is obtained at strips are inserted in the radiator.

Heat transfer coefficient is directly proportional to mass flow rate. In result, from the Figure 11 it is observed that high heat transfer is observed for 7LPM. The heat transfer coefficient difference between water & ethylene glycol/ water is 0.54 to 3%. 5.7 to 10.7% enhancement was observed when using 0.01 – 0.09 volume concentration of Graphene nanofluid. From 0.01 to 0.09 volume concentration of Graphene oxide nanofluid utilization, 8.7 to 10.7% enhancement was observed. It increased up to 22% when Graphene and Graphene oxide nanofluid is utilized in radiator. Similar observation is found when strip is inserted in radiator tubes.

Graphene nanofluid circulating in the radiator tube with strip inserted, the Heat transfer coefficient is enhanced by 236% similarly Graphene oxide nanofluid observed 320%
CONCLUSION

Suspended Nanofluid is a mixture of colloidal suspension of nanoparticles in base fluids. The nanofluids have excellent thermal property enhancement than conventional fluids. These fluids containing nanometer-sized particles. Graphene and Graphene Oxide nanofluids are utilized into the radiator to boost cooling performance and heat transfer. The simulation results are stated in the following statements.

1. 80–86% (50kpa to 74kpa) pressure drop was observed in louvered strip radiator compared with the original radiator model (10 kpa to 10.6 kpa).
2. 4.4 to 6.2°C drop in temperature is observed with water whereas for the water + ethylene glycol 6.4 to 8.2°C drop is observed. It was observed that 34 to 45% (11 to 14°C) of the temperature drop when Graphene and Graphene oxide nanofluid is used with different concentration and mass flow rate. When compared to with and without louvered strip radiator, it was found that 27 to 42 % improvement in temperature drop for louvered strip radiator.
3. 58–60% enhancement of enthalpy observed when Graphene and Graphene oxide nanofluid was utilized.
4. 1.8% of enhancement for entropy is observed in 0.09 volume concentration of the Graphene and Graphene oxide nanofluid at 3LPM when louvered strips are inserted in the radiator
5. With the louvered strip inserted in the radiator, 236% enhancement of heat transfer coefficient is observed for Graphene and Graphene oxide nanofluid is 320% identified.
6. The comparison of Graphene nanofluid used in the radiator and with strip inserted in the radiator, 45% enhancement of heat transfer coefficient is observed and for Graphene oxide nanofluid, 54% improvement identified at 7LPM.

By considering all the above factors, it can be concluded that the performance of Radiator is enhanced with insertion of louvered strip using Graphene based nanofluids with optimum concentration.

ACKNOWLEDGMENTS

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NOMENCLATURE

A  Constant
D  diameter of tube, mm
d  diameter of particle
h  heat transfer coefficient, W/m²·K
There are no ethical issues with the publication of this manuscript.

REFERENCES


AUTHORSHIP CONTRIBUTIONS

M. Sandhya: Conceptualization, Visualization, Investigation, Data curation, Writing - original draft, Writing - review & editing. D. Ramasamy: Supervision, Writing - review & editing. K. Sudhakar: Writing – review & editing. K. Kadigrama: Writing – review & editing. W.S.W. Harun: Writing - review & editing.

DATA AVAILABILITY STATEMENT

No new data were created in this study. The published publication includes all graphics collected or developed during the study.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.


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